Ontario

Ministry of Transportation
Materials Engineering and Research Office Report

Using the MTS 810 Materials Testing System for Characterization of Asphalt Mixtures

MTO Operator's Guide

MERO-026

Technical Report Documentation Page

Publication Title	**Using the MTS 810 Materials Testing System for Characterization of Asphalt Mixtures**
Author(s)	Richard Raciborski Ontario Ministry of Transportation
Originating Office	Bituminous Section, Materials Engineering and Research Office
Report Number	MERO-026; ISBN 978-1-4249-5721-7
Publication Date	December, 2007
Ministry Contact	Bituminous Section, Materials Engineering and Research Office, Ontario Ministry of Transportation, Room 238, Building C, 1201 Wilson Avenue, Downsview, Ontario, Canada M3M 1J8 Tel: 416-235-3715; Fax: 416-235-3996
Abstract	The intent of this manual is to support the transfer of technical knowledge related to the use of the MTS 810 materials testing system, which was installed in the Bituminous Evaluation Laboratory in 1987. It is meant to aid prospective users of the system in safe operation of its loading frame, and in utilizing its versatile capabilities in load generation, displacement control and data acquisition. This manual is based on about 15 years of experience gained by the Bituminous Section staff in operating the system. It gives both general and some detailed insight into operational procedures and complexities of the system. The information, although compiled for internal MERO purposes, may be found useful also for others as a reference in the preparation for more sophisticated laboratory testing of asphalt mixtures and similar materials in the future. The guidelines offered in this manual are neither intended to replace the hands-on operator training by qualified technical staff nor infringe upon the technical contents of the reference documentation provided by the MTS with the testing system. Its purpose is to share the user's experience and provide essential information on the operation of the system in a concise and easy to comprehend format. These guidelines should be read in conjunction with a companion internal publication titled "Bituminous Material Characterization Manual" (by Bituminous Section 1987, ISBN 0-7729-3922-5).
Key Words	MTS 810, materials testing system, operator training, user's guide, automated laboratory testing, asphalt mixtures, asphalt mix characterization, data acquisition, tensile strength test, creep compliance test, resilient modulus test, indirect tensile strength test, dynamic modulus test, flexural fatigue test.
Distribution	Unrestricted technical audience.

Ontario

Ministry of Transportation
Materials Engineering and Research Office Report

MERO-026

Using the MTS 810 Materials Testing System for Characterization of Asphalt Mixtures

December 2007

Prepared by
Richard Raciborski
Bituminous Section
Materials Engineering and Research Office
Ontario Ministry of Transportation

1201 Wilson Avenue,
Downsview, Ontario, Canada M3M 1J8
Tel: 416-235-3715; Fax 416-235-3996

Published without prejudice as to the application of the findings.
Crown copyright reserved.

TABLE OF CONTENTS

EXECUTIVE SUMMARY ii

BACKGROUND 1

SAFETY PRECAUTIONS 2

1.0 COMPONENTS AND BASIC CONTROL OF THE SYSTEM 3

1.1 Components of the System 3
1.2 Manual Control of the Load Unit 3
1.3 Computer Control Modes (Model 793.67 System Software) 5

2.0 ESSENTIAL OPERATING PROCEDURES 6

2.1 System PowerUp / StartUp Sequence 6
2.2 WarmUp Procedure, Positioning the Crosshead 6
2.3 System ShutDown Sequence 7
2.4 Mounting Test Apparatus (Test Fixture) Sequence 8
2.5 Installing the 2.5 kN Load Cell (Force Transducer) Sequence 8

3.0 PRETEST PREPARATIONS 10

4.0 DIRECT TENSILE STRENGTH TEST 11

4.1 Test Procedure Outline 11
4.2 Setup Sequence for Direct Tensile Strength Test 12
4.3 Preparation for the Crack Sealant Pullout Test in Basic TestWare Environment 13
4.4 Output / Results 14

5.0 CREEP COMPLIANCE / TENSILE STRENGTH / RESILIENT MODULUS, USING INDIRECT TENSILE TEST FIXTURE 15

5.1 Outline of Test Procedures 15
5.1.1 Creep Compliance and Indirect Tensile Strength Test *15*
5.1.2 Resilient Modulus Test *17*
5.2 Setup for the Tests 17
5.3 Output / Results 19

6.0 DYNAMIC MODULUS TEST 20

6.1 Test Procedure Outline 20
6.2 Setup for the Test 21
6.3 Output / Results 23

7.0 FLEXURAL FATIGUE TEST 25

7.1 Test Procedure Outline 25
7.2 Setup for the Test 26
7.3 Output / Results 28

8.0 ACKNOWLEDGEMENTS 29

9.0 REFERENCES 30

Executive Summary

The intent of this report is to support the transfer of technical knowledge in laboratory testing of asphalt mixtures using the MTS materials testing system. This closed-loop MTS 810 model was installed in the Bituminous Evaluation Lab in early 1987 with aim to update the in-house capability for studying the fundamental properties of asphalt paving materials. The importance of this study was later reaffirmed by U.S. Strategic Highway Research Program (SHRP). Since then, this machine has been used in various research and developmental projects.

At the time of the study program, Bituminous Section of the then Engineering Materials Office, has published a "Bituminous Material Characterization Manual" (by Bituminous Section 1987, ISBN 0-7729-3922-5) to provide a synopsis on the state-of-the-art information on methods, theories, applications, interpretation of results, and acceptance criteria. It is suggested that the guidelines should be read in conjunction with this companion internal publication.

Operating the equipment requires a broad range of technical skills and experience. Actual testing of asphalt specimens is even more demanding and must be supported by good knowledge of the computer operating system and all relevant application software, some real-time programming skills, as well as dedication and patience.

This is a manual-format report, which has been specifically prepared to guide potential operators and users of the MTS system through operational basics and testing sequences involved in testing procedures used in evaluation of asphalt mixtures or similar materials. It summarizes the operational knowledge and experience acquired with the MTS 810 system in the Bituminous Section.

The equipment operation safety precautions are emphasized in several sections throughout the manual. Components and basic control of the system are covered in the first chapter. Steps and processes involved in operating the equipment are described in the second chapter. The third chapter covers steps involved in pre-test preparations. In the following chapters there are outlines of most frequently used test procedures, what each test setup consists of and their proper sequencing. Expected test output/results are also covered briefly. Reference items are provided at the end of the manual.

Although the manual is prepared for the specific MTS 810 model and related TestStar IIs software used in the Bituminous Section, it can also serve as a useful example/reference tool for users of similar testing systems outside the MTO.

Background

In early 1987, the Bituminous Evaluation Laboratory, Engineering Materials Office acquired and had installed the servo-hydraulic Materials Testing System (MTS Model 810). Originally, the equipment came with RT-11 v. 5.2 operating system and the MTS 773 MU BASIC language tools. Using those tools, seven test programs were developed during 1987 through 1989 to automate the testing for asphalt mixtures. Since then, a variety of tests using those programs have been carried out.

In 2001, some essential parts of the system hardware were modernized and the system software plus application software was replaced/updated in its entirety with newly developed MTS software. Currently, in 2007, the system is controlled using a personal computer with Windows NT v. 4.0 system software. The MTS Station Manager application software is now used to operate the MTS 810 load frame.

The Station Manager allows controlling the load frame in three modes. Although some simple tests can be run without special programming, most of the testing methods require the user to design and develop testing procedures in a so-called Multi-Purpose Testware (MPT) environment. Such procedures can then be used for multiple specimens and projects. In recent years, some procedures were developed and used on an as needed basis in the Bituminous Section.

This report is essentially based on that developmental work and the associated operational experience. Within that scope it also utilizes the experience of hands-on 5-day operator training provided to the lab staff of Bituminous Section in the summer of 2006. Those training sessions, although informal, provided opportunity for summarizing the lessons learned over nearly two decades of operating the MTS system and testing the asphalt mixtures.

Safety Precautions

- Read and understand the MTS Operator's Safety Practices, Section VI, in the MTS User's Manual accompanying the MTO testing system.
- DO NOT use the machine until you receive personal training from an experienced operator. DO NOT work alone in the lab when operating the system.
- Only ONE person at a time can be in charge of the testing system. If you are that person, others should know how to turn power OFF in the event of emergency.
- Take care that during the servo-hydraulic system operation hands and other body parts are never in the direct path of any active component. Wear personal safety gear to prevent particularly your eyes, hands and feet from injury.
- The MTS machine is a fast servo-hydraulic machine. Improper or careless use of the system, or computer malfunction, can cause a serious personal injury and damage to your equipment and specimen.
- MTS support is available at 1-800-328-2255. When calling for information or advice regarding the system operation or malfunctioning/troubleshooting, quote your site number (#50667 for Bituminous Evaluation Laboratory).

<u>This is NOT a complete guide or reference material</u>.

The MTS system operator should read all supplied manuals and have had prior training on MTS 810 or similar electro-hydraulic closed-loop systems. The operator must also be familiar with the use of Windows NT 4.0 operating system and its applications.

1.0 Components and Basic Control of the System

1.1 COMPONENTS OF THE SYSTEM

The main hardware components of the system:

- MTS 810 load frame with linear actuator, adjustable crosshead, load transducers (100 and 2.5 kN), grips, and the controls (locks),
- Personal computer system with Station Manager v. 3.1B,
- Remote station controller (RSC or Pod for short),
- Hydraulic pump, service manifold and grip supply,
- MTS control unit (TestStar IIs),
- Temperature controller,
- Environmental chamber.

TestStar IIs Station Manager is the main program for operating the MTS load frame. It provides:

- Menus for activating the hydraulics to move the actuator and grip specimens, and
- Windows for displaying the system information, either textually or graphically (oscilloscope-wise).

The hydraulic power system can be operated AUTOMATICALLY by a PC (running Windows NT 4.0) or MANUALLY i.e. using the RSC.

The actuator can be controlled either by FORCE or DISPLACEMENT.

The RSC is a dedicated control panel for manually controlling the MTS station. It is used primarily when attaching/mounting fixtures, loading specimens and running some simple pre-defined tests.

1.2 MANUAL CONTROL OF THE LOAD UNIT

To use the manual control you need to be in **Station Manager application** and activate the control by pressing the "Enable/Disable" button on the RSC panel.

The RSC has a series of buttons (positioning, indicating and controlling) and a digital programmable display (see Figure 1) that shows sensor outputs and the current control mode.

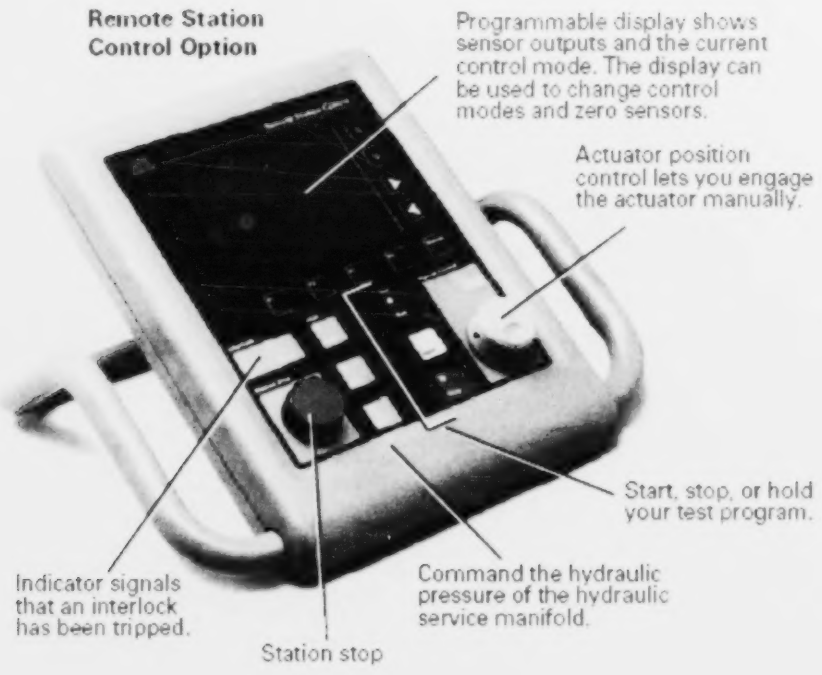
Remote Station
Control Option
Programmable display shows sensor outputs and the current control mode. The display can be used to change control modes and zero sensors.
Actuator position control lets you engage the actuator manually.
Start, stop, or hold your test program.
Command the hydraulic pressure of the hydraulic service manifold.
Indicator signals that an interlock has been tripped.
Station stop

Figure 1 - Remote Station Controller (RSC)

The control buttons of the RSC can be used for any of the following functions:

- To command the hydraulic pressure of the hydraulic service manifold,
- To engage the actuator and control its position,
- To start, stop or hold your test program,
- To STOP the machine in EMERGENCY (red button).

The interlock indicator button signals that an interlock has been tripped and needs to be reset.

The display shows the current control mode and sensor outputs. It can be used to change control modes and zero sensors if needed.

The RSC can also be used when you're running the **MPT application**, but for different functions:

- To create a new test (specimen) (F1 button),
- To reset the current test and start another one (F2 button),
- To toggle between Execute & Edit modes of current procedure (F4 button).

Note: when a specimen is selected in the MPT application, the RSC is switched automatically to MPT control.

1.3 COMPUTER CONTROL MODES (MODEL 793.67 SYSTEM SOFTWARE)

There are three computer-run applications/modes you can select from Station Controls panel displayed in Station Manager window.

Function Generator Application

Use it when you want to generate waves of specific amplitude, frequency and shapes available, e.g. to warm-up the machine prior to testing specimens.

Basic TestWare Application

Use it if you want to run a simple test procedure (monotonic or cyclic) such as a simple compression test with basic data acquisition and monitoring without any procedural design.

MPT Application

Use it when you want either to run an available (already designed) test procedure or to edit/design a new test procedure and save it for multiple specimens/projects.

2.0 Essential Operating Procedures

2.1 SYSTEM POWER-UP / START-UP SEQUENCE

1. Turn water on for the hydraulic pump.
2. Turn the computer and the TestStar IIs controller ON.
3. Wait for the Windows NT desktop screen to appear. Note the powering up Green and Amber lights on the front panel of the TestStar.
4. Wait for the Amber light to turn OFF.
5. Adjust the dimmer switch of the RSC to view its display clearly.
6. Double click on the Station Manager icon to load it.
7. Select an available/desired Station configuration file (*.cfg). The RSC is activated at this point and the actuator can now be controlled manually. The Station Manager, handling the RSC, provides menus for activating the hydraulics and various windows displaying system information and test definition.
8. Select next step depending on a planned action.

2.2 WARM-UP PROCEDURE, POSITIONING THE CROSSHEAD

A warm-up routine should be run at the beginning of each testing day. The actuator is usually cycled at 5 to 8 cm amplitude for about half an hour.

(The hydraulic fluid should be warm at the start of a test procedure so that the actuator motion can be controlled accurately.)

While in Station Manager, follow these steps:

1. Choose a warm-up procedure template (e.g. "Warmup.000") and select "Execute Procedure" from the procedure menu. DON'T START IT YET.
2. Using the RSC, first press the HPS "Low" button, then – when the low power icon stops blinking – the "High" button.
3. Press the HSM "Low" button, then the "High" button.
4. Enable the manual control at the RSC.
5. Check the crosshead position at this point. A proper crosshead position usually varies depending on a test procedure you want to run next. If you don't need to change **the crosshead position**, go to step 6, otherwise proceed as follows:

For your safety note this:

> Do not unlock the crosshead without **high** hydraulic pressure and lift controls in the 0 (central) position. The crosshead can drop down unexpectedly, if these conditions are not met.
>
> The load unit columns must be free of any lubricant; otherwise, the crosshead locks may not operate properly.

a) Adjust the Hydraulic Lifts Control slightly (counterclockwise), then return it to the null position,

b) Unlock the Hydraulic Locks Control (counterclockwise).

c) Wait at least 30 seconds.

d) Adjust the Hydraulic Lifts Control to move the crosshead up or down and position it slightly above the desired position. Then, adjust the Control slightly clockwise to lower the crosshead and turn the Lifts Control to the null (central) position,

e) Rotate the Hydraulic Locks Control clockwise to the Lock position.

6. Make sure that "Displacement" control mode is selected on the RSC digital display; if not, move the cursor to highlight mode selection area and press the "Next" button until "Displacement" is selected.
7. Position the actuator, using the positioning control knob, in its center position (approx. 12.5 cm above its bottom position).
8. Turn the Manual control OFF.
9. Move the cursor in the digital display until the "Displacement" mode is selected, and push F1 button to set the ZERO reference for the actuator's stroke.
10. Move the cursor in the digital display until the "Force" mode is selected, and push F1 button to set the ZERO reference for the actuator's load.
11. Now press the Green "Run" button on the RSC, or use computer control to start the warm-up procedure.

2.3 SYSTEM SHUT-DOWN SEQUENCE

1. Push the HSM "Low" pressure button, followed in a few seconds by pushing the hydraulics OFF button.
2. Close the Station Manager on the computer.
3. Shut down the computer.
4. Turn OFF the power to the TestStar controller and computer.

2.4 MOUNTING TEST APPARATUS (TEST FIXTURE) SEQUENCE

Test apparatus mounting or specimen installation can be a potentially hazardous procedure and requires extra caution.

1. With high hydraulic pressure applied, in Displacement control, fully retract the actuator.
2. Switch the system to Force control.

   NOTE: It is important to be in Force control mode when closing the upper (second) grip. The control system in this mode will try to keep the load close to zero (i.e. at its current level). When the system is in Displacement control, the controller will try to keep the actuator in the same position and any deviation from that position can put relatively high force on the rigid structure of test apparatus or specimen when the grips are closed.

3. Insert the lower connector (steel rod) of the test fixture in the lower grip, allowing 3 to 6 mm between the bottom of the rod and the bottom inner edges of the grip wedges. Lock the lower grip.
4. Extend the actuator until the upper connector (steel rod) is positioned in the upper grip, allowing a space 3 to 6 mm between the top of the rod and the inner top edges of the grip wedges.
5. Lock the upper grip and immediately adjust the Force output to zero.

2.5 INSTALLING THE 2.5 KN LOAD CELL (FORCE TRANSDUCER) SEQUENCE

Before proceeding with installation the operator shall become familia with all operating aspects of the system electronic controls and interloc restrictions applicable to the system.

1. Turn ON the system hydraulic pressure.
2. While in Displacement control at the RSC, raise the actuator halfway above its bottom position.
3. Adjust the position of the crosshead to accommodate the length of the steel rod (a coupling) used normally for this purpose.
4. Insert the rod into the upper grip, allowing a 3 to 6 mm space between the top of the rod and the inner top edges of the grip wedges, and lock it in place.
5. Insert the lower end of the rod into the lower grip by carefully raising the actuator up, allowing a space of 3 to 6 mm between the bottom of the rod and the bottom inner edges of the grip wedges. Lock the lower grip.

6. Switch to Force control, zero the load, and apply a tensile load of 10 to 20% greater then the maximum load expected during testing.
7. Using two spanner wrenches, loosen the spiral washers (on the stud connecting the force transducer and the upper grip) by rotating them in opposite directions to reduce their combined thickness to a minimum.
8. Release the load.
9. Release the grips and remove the rod.
10. Turn the hydraulic pressure OFF. Make sure that the pressure has been reduced to zero (actuator not moving).
11. Remove hydraulic hose from the load cell.
12. Plug up the hose as necessary.
13. Switch to Displacement control.
14. Place a soft base (e.g. a thick towel or a wooden block) on the top of the lower grip and raise the actuator to support the upper grip during unloading.
15. Remove the upper grip and carefully position it on top of the soft base.
16. Install the 2.5 kN load cell.
17. Attach the hydraulic hose (matching cable).
18. Slowly raise the lower grip until the stud on the upper grip just makes contact with the newly mounted force transducer.
19. Install the upper grip back on. Be careful to align the thread properly, then slowly screw the grip into the 2.5 kN force transducer until it is snug.
20. Switch to force control and, with the steel rod inserted and gripped, apply tensile load 10 to 20% greater than the maximum force expected during testing, to provide tension to the threads and tighten the spiral washers.
21. Using two spanner wrenches, rotate the two halves of the spiral washers in opposite directions to tighten them. The opening between the washers must not exceed an arc of 30° from the closed position.
22. Reduce tensile force to zero and remove the steel rod.
23. Turn OFF the system hydraulic pressure.
24. Check the alignment between the upper and lower grips. Align the grip wedge openings, if necessary.
25. Activate the appropriate driver file for the newly installed load cell (force transducer).

3.0 Pre-Test Preparations

Prior to using the MTS System, at the test planning stage, you have to know:

- Standard and specifications to be followed,
- Capability of the MTS 810 testing system,
- Required fixture, grips and sensors/ instruments needed for the test,
- Expected material strength (must be below max. capability of the system),
- Rate(s) of strain/displacement or load to be applied,
- Test temperature and other applicable test parameters,
- The MTS support line (1-800-328-2255) and laboratory site number (MTO site number 50667).

Prior to running a designed test procedure for the first time you have to follow these essential steps:

- Create a configuration file with the Station Builder application; this application allows you to allocate controller resources to a station configuration file,
- Tune control channels,
- Calibrate sensors / conditioners,
- Set Station limits,
- Set up readout devices (like Input Signals, Detectors, Meters, Scope) to monitor signals / test progress,
- Set a timetable and sequence of testing (plan for your days testing).

4.0 Direct Tensile Strength Test

4.1 TEST PROCEDURE OUTLINE

This test method is used to determine the tensile strength of compacted bituminous mixtures or to investigate tensile load/stress characteristics at break of a bond between bituminous mixtures and other materials, which they adhere to.

The test applies either:

- a continuously increasing vertical displacement in tension at a predetermined rate, or
- an initial tensile load to the specimen followed by preventing any thermal contraction of the specimen while it is cooled at a given rate.

This process continues until some kind of tensile failure occurs.

It can be used to carry out tensile strength test for a restrained specimen, e.g. based on some aspects of AASHTO TP10 ("Thermal Stress Restrained Specimen Tensile Strength") or to investigate tensile strength in custom configurations of composite bituminous materials, like e.g. a pullout test, as shown here in Figure 2.

The test can be ended normally in two ways: either when displacement reaches a predetermined amount (e.g. 200 mm) or when applied tensile load declines by some percentage below the maximum load (e.g. 40%) recorded during testing. An operator can select one of these events, indicating specimen failure, during test setup (preparatory stage of the test) using the MPT Testware. The operator can also terminate the test manually, if necessary.

If data acquisition is required for the test, the following signals should normally be specified and directed to a data file:

- time, s
- axial displacement, mm
- axial force, N.

The acquired data can also be plotted and displayed on screen in real time during the test. Plot Setup window should be used to set up and enable the plotting.

For more details on Command Generation, Data Collection, Plots and Failure Detection, refer to the MTS "TestStar IIs Asphalt Testing" manual, or to the help files installed with the MTS software package.

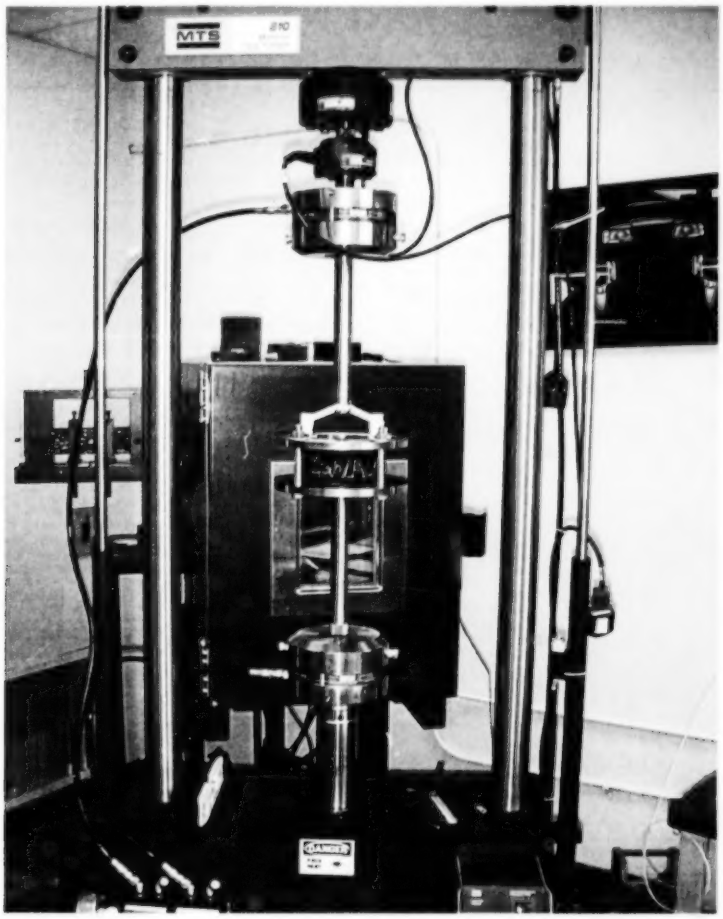

Figure 2 - Setup for Tensile Test – Pullout of Crack Sealant

4.2 SETUP SEQUENCE FOR DIRECT TENSILE STRENGTH TEST

- Activate the computer and TestStar IIs controller, if this is not done yet.
- Open Station Manager application and – if it is the first test of the day - run a Warm-Up procedure (see Section 2.2).
- Prepare test specimen and mount it in its designated fixture.
- Attach the specimen calibrated transducers and cables (if applicable).
- Select/open appropriate station configuration file (*.cfg); it contains a list of station resources / station parameter sets, applicable to your test procedure.
- Select the program source on the main panel, either Function Generator, Basic TestWare or MPT TestWare, depending on the requirements of applicable specifications.

If the wanted tensile test procedure has already been programmed and saved, select and Open your Procedure from the File menu. If a new or modified tensile test program is needed, select appropriate TestWare environment and design the test sequence using commands, data acquisition processes and other elements available in the TestWare toolbars.

If you need to use the MPT environment for testing then you must select or create so-called "Specimen" before attempting to run a test procedure.

This is a special folder (directory) on your computer where all information about execution of a particular test will go. You must provide a name for this "Specimen"; otherwise MPT will display an error message. It should be a unique name, unless you want either to append new test information to the existing data files or to write over some existing information.

4.3 PREPARATION FOR THE CRACK SEALANT PULLOUT TEST IN BASIC TESTWARE ENVIRONMENT

Crack Sealant Pullout (Direct Tension) Test procedure was developed in the Ministry's Bituminous Section. It is a relatively simple case of a monotonic test run under Displacement control and can be carried out in **Basic TestWare** environment.

The test was used to investigate asphalt sealant compatibility with the bituminous specimen substrate material by determining the resistance of a sealant to being pulled out of a U-shaped grove at a constant rate of 50.8 mm/min, while the specimen was positioned in a special fixture designed for the test.

To execute the test using ***Basic Testware*** proceed as follows:

1. Define the subdirectory name (the specimen) for the current set of test data and the file mode (overwrite or append).
2. Define data export format (select "Excel").
3. Save the test parameters, if changed/edited.
4. Reset the station software interlocks (if vertical Red bars are present the hydraulic system will not start).
5. Start the hydraulic pump at the RSC (Low, then High), and then enable the Manual control.
6. Adjust the crosshead first and then the actuator positions as necessary.

   Move the actuator slowly and make sure that you don't put any excessive force/pressure on the specimen. Take care so that the actuator is not fully extended to its top position; the hydraulic controls do not function properly when the actuator is at the very top or bottom positions.
7. Install the fixture with a specimen into top or bottom (depending on the fixture) grips, making sure that the fixture and test specimen are properly (symmetrically) aligned.

8. Turn off Manual control at the RSC.
9. Move the cursor until the Displacement reading is selected, then push the F1 button; this will set the Zero reference for Force.
10. Move the cursor until the Force reading is selected, then push the F1 button; this will set the Zero reference for Displacement.
11. Clamp firmly the bottom or top grip (depending on the fixture used). Take care not to damage the specimen while clamping.
12. Reset any active interlocks, if necessary, and Start the tensile test by either pushing the green Run button on the RSC, or using computer control (after switching to the Execute Mode, if in the MPT procedure window).
13. When specimen breaks, or reaches desired displacement limit, push the orange Hold button and remove the tested specimen safely (!)
14. Push the red Stop button to complete the procedure.

4.4 OUTPUT / RESULTS

Data collected during the test are automatically saved in a file called *specimen.dat*, in the folder created for the *specific specimen* tested.

To access the data, select ***Example Report Generator*** item under ***Programs> MTS Civil Engineering Materials Testing*** subdirectory. This selection will launch Excel version with an MTS menu. On the MTS menu, point to ***Data*** and click ***Open Raw Data***. Now locate and open the desired data file, i.e. ***specimen.dat*** in the subdirectory for your tested specimen.

At this point the data file can be saved in Excel format (*.xls), with the Operator's choice of subdirectory and filename. Now the data can be analyzed using either an existing Excel template created earlier for this type of test, or in a customized spreadsheet format if such was designed for the specific purpose of a testing program.

Report on the Tensile Strength Test results should include:

- description or type of hot mix asphalt and crack sealant (if used in the test),
- specimen configuration and dimensions,
- average test temperature,
- extension/deformation rate, or load increase rate (if in load control)
- ultimate tensile load reached,
- extension at the ultimate tensile load,
- stiffness at ultimate load (if applicable),
- plot of tensile load vs. time, and
- plot of vertical deformation vs. tensile load.

5.0 Creep Compliance / Tensile Strength / Resilient Modulus, Using Indirect Tensile Test Fixture

(AASHTO T322 Test Method)

5.1 OUTLINE OF TEST PROCEDURES

5.1.1 CREEP COMPLIANCE AND INDIRECT TENSILE STRENGTH TEST

This test procedure combines the tensile creep and tensile strength procedures carried out on gyratory-size specimens usually 38 to 50 mm high. The tensile strength is determined either immediately after the tensile creep testing or in a separate test run by applying a constant rate of vertical deformation to failure.

The procedures are used to characterize the susceptibility of hot mix asphalt to thermal cracking (resistance to tensile fracture) and to determine its tensile strength, which is needed for fatigue cracking analyses. These hot mix asphalt characteristics are applied/required in Superpave mix design verification (levels 2 and 3).

A special indirect tensile test fixture, specimen deformation measurement devices (accurately positioned, using a mounting template, eight gage points and four appropriate LVDTs), and environmental chamber equipped with temperature conditioners and controls, are required for this procedure to be carried out successfully.

A general diagrammatic view of specimen loading frame is illustrated in Figure 3. Please refer to the AASHTO T322 Test Method for further details on the apparatus.

In the creep compliance test a static load is applied vertically at a specified temperature for 1000 s, and the recorded horizontal and vertical deformations are used to calculate the creep compliance over time.

In the indirect tensile strength test the specimen is loaded vertically at a rate of 50 mm/min until the load begins to decrease (to failure).

All details of specifications for both procedures, including calculations, are provided in the AASHTO T322 Test Method.

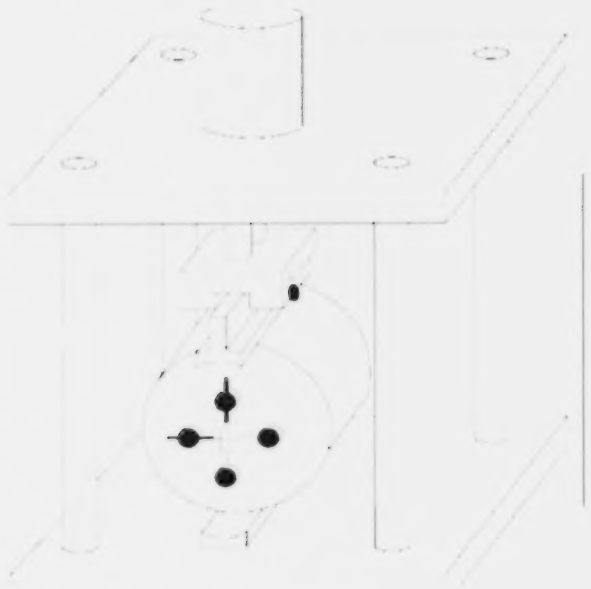

Figure 3 - Schematic of Specimen Loading Frame Used for Creep Compliance, Resilient Modulus, and Indirect Tensile Strength Tests

Data collection during the test procedure should include the following signals:

- time,s
- axial stroke,
- axial load (master signal),
- vertical displacement – face 1,
- vertical displacement – face 2,
- horizontal displacement – face 1,
- horizontal displacement – face 2.

These signals are typically collected in **timed processes**, at 1.0 s intervals, as well as in **level crossing processes**. The Operator should specify the desired value for the level increment, which refers to the master signal. When the level of the axial load changes by the specified increment, data collection is triggered for all other processes in the list.

After the creep test (fixed load over 1000 s) has been applied or reapplied, the tensile strength is determined by applying a displacement-controlled load at a constant rate specified. To determine the specimen strength, a failure criterion must be defined. Failure detection is just another important element of data acquisition processes. The Operator should define the failure criterion as the % of change, e.g. 75%, in the load value in relation to the initial load value at which the failure detector process triggers.

In addition to the data acquisition, the Operator can also define and enable up to nine separate plots for display. Please refer to Chapter 4 in "TestStar IIs Asphalt Testing" manual for all the details regarding both the data acquisition and plotting processes.

5.1.2 RESILIENT MODULUS TEST

This test procedure is run using essentially the same configuration (setup) as described for the Creep Compliance and the Indirect Tensile Strength procedures. A cyclic (haversine) stress of fixed amplitude, typically with pulse duration of 0.1 s and a rest period of 0.9 s, is applied to the test specimen. The deformation responses of the specimen are used to calculate both an instantaneous and total Poisson's ratio, and based on that – an instantaneous and total resilient modulus.

The value of resilient modulus is a measure of the elastic modulus of hot mix asphalt recognizing its non-linear characteristics. It provides a means of characterizing the asphalt under various temperatures and stresses that simulate pavement conditions subjected to moving (dynamic) loads. Resilient modulus values can be used with pavement structural response models and with pavement design procedures.

5.2 SETUP FOR THE TESTS

- Activate the computer and TestStar IIs controller, if this is not done yet.
- Open Station Manager application and – if it is the first test of the day - run a Warm-Up procedure (see Section 2.2).
- Ensure that the actuator and crosshead are properly positioned for the test.
- Install your indirect tensile test fixture securely.
- Prepare test specimen, instrument it as specified and place in its fixture on a lower loading strip.
- Attach the specimen calibrated transducers and cables, and connect them to the appropriate input channels on the back panel of the TestStar IIs controller.
- Select/open appropriate station configuration file (*.cfg), which contains a list of station resources / station parameter sets, applicable to your test procedure.
- Select the program source, MPT TestWare, on the main panel.

  If the AASHTO T322 test procedure has already been programmed and saved, select and Open your Procedure from the File menu. If the test procedure needs to designed or modified, select the MPT TestWare environment and (re)design the test sequence by (re)defining the entire sequence of events that are to take place within the test, using the tools available within the MPT programming environment. This requires some TestStar-specific programming experience.

Once the testing procedure is selected and opened, follow these steps.

1. Start the hydraulic pump (Low, then High) at the RSC, if not running at this point, and then enable the Manual control.
2. Use the Manual control knob to bring the specimen carefully into contact with the upper loading strip.

Move the actuator slowly and make sure that you don't put any excessive force/pressure on the specimen. Take care so that the actuator is not fully extended to its top position; the hydraulic controls do not function properly when the actuator is at the very top or bottom positions.

3. Switch to Force control and adjust contact load to an acceptable value, not exceeding approximately 5% of the test load.
4. Position the specimen so that the load strip alignment mark on the test specimen lines up with the loading strips, on both faces of the specimen. Make sure that the contact surface between specimen and each loading strip is continuous
5. Zero or rebalance the electronic measuring system.

   The sensors/transducers should show stable readings, drifting usually no more than 10 to 50 μstrains over 100 seconds). This demonstrates that the specimen is stabilized at a current test temperature.

6. Make sure that the contact surface between specimen and each loading strip is continuous (no major projections or depressions extending more than e.g. 12 mm).
7. After stability of the measuring sensors is achieved, turn the Manual control OFF at the RSC.
8. On the MPT Control Panel, select an existing or create a new so-called "Specimen" before attempting to run the test procedure.

   This is a special folder (subdirectory) on your computer where all information about execution of a particular test will go. You must provide a name for this "Specimen"; otherwise MPT will display an error message. It should be a unique name, unless you want either to append new test information to the existing data files or to write over some existing information.

9. Reset any active interlocks (if vertical Red bars are present the procedure will not start).
10. Before starting the test, ensure again that the specimen is installed properly, sensors are attached and their outputs have been zeroed, and the actuator is properly positioned.
11. Switch to the **execute mode** by clicking the Padlock button on the MPT Control Panel.
12. Start the procedure by clicking the **Run** button on the MPT Control Panel.
13. When Pre-Test/Specimen information is required, fill in or change the information as necessary and click OK.
14. Click the **Start** button on the MPT Control Panel to continue the procedure.
15. Watch the procedure executing. You can click **Terminate** button any time during test execution to stop the procedure when necessary.

> If the system becomes unstable at any point, immediately press the **Emergency** STOP button at the RSC to remove hydraulic pressure. Identify the cause of the instability before attempting the test again.

16. When test is completed normally (successfully), enter the post-test information, if required, to finalize/exit the procedure.

    Note
    You can also stop the test (interrupt) *normally* at any time by clicking on **Stop** button on the main MPT panel. System will then return to Setpoint levels.

5.3 OUTPUT / RESULTS

Data collected during the test are automatically saved in a file called *specimen.dat*, in the folder created for the *specific specimen* tested.

To access the data, select ***Example Report Generator*** item under ***Programs> MTS Civil Engineering Materials Testing*** subdirectory. This selection will launch Excel version with an MTS menu. On the MTS menu, point to ***Data*** and click ***Open Raw Data***. From here locate and open the desired data file, i.e. ***specimen.dat*** in the subdirectory for your tested specimen.

At this point the Operator can select to use the MTS data analysis template (by pointing, on the MTS menu, to Test Definition -> Asphalt, and clicking the ***Indirect Tensile Creep*** or ***Resilient Modulus***, as appropriate) and proceed with data analysis, the MTS way.

Otherwise, the data file can be saved in Excel format (*.xls), with the Operator's choice of subdirectory and filename. The data can subsequently be analyzed using a customized spreadsheet template if such a template has been or will be developed in-house for this specific purpose.

Report on the Indirect Tensile Creep Compliance and Strength Test results should include:

- hot mix asphalt description, including densities,
- specimen dimensions,
- average test temperature,
- applied load levels during the test,
- tensile creep compliance values as computed,
- tensile strength of the mix,
- plot of creep compliance vs. time, and
- plot of vertical deformation vs. load cycles.

Report on the Resilience Modulus Test results should include:

- hot mix asphalt description,
- specimen dimensions,
- average test temperature,
- applied load levels during the test,
- load cycle characteristics,
- Poisson's ratios – instantaneous and total, and
- resilient modulus values – instantaneous and total.

6.0 Dynamic Modulus Test

(AASHTO TP62, ASTM D3497)

6.1 TEST PROCEDURE OUTLINE

This test procedure is carried out on asphalt mix specimens having a minimum diameter of 101.6 mm and height-to-diameter ratio of 2 to 1.

The dynamic modulus measured over a range of temperatures and frequencies of loading can be shifted into a master curve. The master curve characterizes hot mix asphalt response under sinusoidal loading conditions and is one of the most important inputs needed for the mechanistic pavement design, as well as for evaluation of asphalt mixture designs and performance analysis.

Diagrammatic view of test setup is shown in Figure 4.

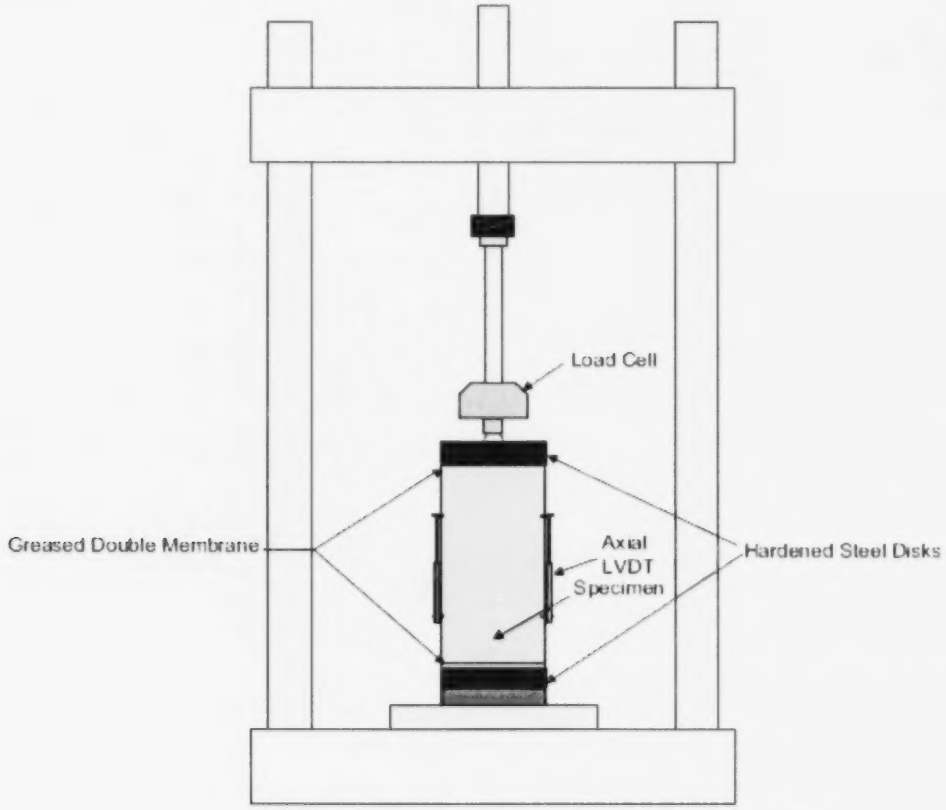

Figure 4. General Schematic of Dynamic Modulus Test

A haversine axial compression load, with maximum value of 241 kPa, is applied to a specimen for 30 to 45 s, at each of given temperatures and loading frequencies of 1, 4, and 16 Hz. If specimen deformation is expected to exceed 2500 μstrains, the Operator should select a lower load value, 121 kPa, for the test rather than 241 kPa. Complete set of tests on a single specimen includes testing at three different temperatures: 5, 25 and 40°C).

Data collection during the test procedure includes the following signals:

- time,s
- axial load amplitude levels (peaks and valleys) for load applied to the specimen; the test is run in load phase amplitude control,
- axial displacement amplitude levels (peaks and valleys) for each of installed LVDTs.

The load ramps to a specified level and cycles between this end level and a second end level at a specified rate for a specified number of cycles.

The test ends normally when the specimen is cycled the specified length of time at each of the specified frequencies, for a given temperature.

The acquired data can also be plotted and updated on screen at selected intervals during the test. This update rate should be set at moderate level, e.g. every 3 to 5 seconds; otherwise the plotter may not be able to keep up due to the time needed for computer calculations taking place in real time.

For more details on Command Generation, Data Collection, Limit Detection, and Plotting, please refer to the MTS "TestStar IIs Asphalt Testing Manual", Chapter 2, or to the help files installed with the MTS software package.

6.2 SETUP FOR THE TEST

- Activate the computer and TestStar IIs controller, if this is not done yet.
- Open Station Manager application and – if it is the first test of the day - run a Warm-Up procedure.
- Ensure that the actuator and crosshead are properly positioned for the test.
- Install your lower end plate (hardened steel disk) securely in the lower grip.
- Prepare test specimen and place it on the plate. Make sure that the contact surfaces of the specimen are parallel to each other.

  Teflon paper can be used to reduce friction at the end plates.

- Attach the specimen calibrated transducers (e.g. two or three MTS extensometers with a 114-mm gage length) and cables, and connect them to the appropriate channels on the back panel of the TestStar IIs controller. Adjust the transducers to near the end of its linear range.
- Select/open appropriate station configuration file (*.cfg), which contains a list of station resources / station parameter sets, applicable to your test procedure.

- Select the program source, MPT TestWare, on the main panel.

  If the AASHTO TP62 or ASTM D3497 test procedure has already been programmed and saved, select and Open your Procedure from the File menu. If the test procedure needs to be designed or modified, select the MPT TestWare environment and (re)design the test sequence by (re)defining the entire sequence of events that are to take place within the test, using the tools available within the MPT programming environment. This requires some TestStar-specific programming experience.

Once the testing procedure is selected and opened, follow these steps:

1. Start the hydraulic pump (Low, then High) at the RSC, if not running at this point, and then enable the Manual control.
2. Install the upper end plate securely in the upper grip.
3. Use the Manual control knob to bring the specimen carefully into contact with the upper loading plate.

   Move the actuator slowly and make sure that you don't put any excessive force/pressure on the specimen. Take care so that the actuator is not fully extended to its top position; the hydraulic controls do not function properly when the actuator is at the very top or bottom positions.
4. Switch to Force control and adjust contact load to an acceptable value, ensuring a positive contact during the test but not exceeding approximately 5% of the dynamic test load.
5. Adjust the specimen position, if necessary, to ensure that it is centered in relation to the loading plates (Avoid eccentric loading!).
6. Zero or rebalance the electronic measuring system.

   The sensors/transducers should show stable readings, drifting no more than e.g. 10 to 50 μstrains over 100 seconds). This demonstrates that the specimen is stabilized at a current test temperature.
7. After the measuring sensors stability is achieved, turn the Manual control OFF at the RSC.
8. On the MPT Control Panel, select an existing or create a new so-called "Specimen" before attempting to run the test procedure.

   This is a special folder (subdirectory) on your computer where all information about execution of a particular test will go. You must provide a name for this "Specimen"; otherwise MPT will display an error message. It should be a unique name, unless you want either to append new test information to the existing data files or to write over some existing information. Reset the station software interlocks (if vertical Red bars are present the hydraulic system will not start).
9. Reset any active interlocks (if vertical Red bars are present the procedure will not start).
10. Before starting the test, ensure again that the specimen is installed properly, sensors are attached and their outputs have been zeroed, and the actuator is properly positioned (the contact load is steady).

11. Switch to the **execute mode** by clicking the Padlock button on the MPT Control Panel.
12. Start the procedure by clicking the **Run** button on the MPT Control Panel.
13. When Pre-Test/Specimen information is required, fill in or change the information as necessary and click OK.
14. Click the **Start** button on the MPT Control Panel to continue the procedure.
15. Watch the procedure executing. You can click **Terminate** button any time during test execution to stop the procedure when necessary.

> If the system becomes unstable at any point, immediately press the **Emergency** STOP button at the RSC to remove hydraulic pressure. Identify the cause of the instability before attempting the test again.

16. When test is completed normally (successfully), enter the post-test information, if required, to finalize/exit the procedure.

    Note
    You can also stop the test (interrupt) *normally* at any time by clicking on **Stop** button on the main MPT panel. System will then return to Setpoint levels.

6.3 OUTPUT / RESULTS

Data collected during the test are automatically saved in a file called *specimen.dat*, in the folder created for the *specific specimen* tested.

To access the data, select ***Example Report Generator*** item under ***Programs> MTS Civil Engineering Materials Testing*** subdirectory. This selection will launch Excel version with an MTS menu. On the MTS menu, point to ***Data*** and click ***Open Raw Data***. From here locate and open the desired data file, i.e. ***specimen.dat*** in the subdirectory for your tested specimen.

At this point the Operator can select to use the MTS data analysis template (by pointing, on the MTS menu, to Test Definition -> Asphalt, and clicking the **Dynamic Modulus**) and proceed with data analysis, the MTS way.

Otherwise, the data file can be saved in Excel format (*.xls), with the Operator's choice of subdirectory and filename. The data can subsequently be analyzed using a customized spreadsheet template if such a template has been or will be developed in-house for this specific purpose.

Report on test results should include:

- hot mix asphalt description,
- specimen dimensions,

- average test temperature,
- average dynamic modulus for 1, 4 and 16-Hz loading frequencies.
- plot of load and strain recorded during the test.

7.0 Flexural Fatigue Test

(AASHTO T321)

7.1 TEST PROCEDURE OUTLINE

This test procedure is carried out on beam specimens 380 mm long by 50 mm thick by 63 mm wide, sawed from laboratory or field compacted hot mix asphalt. All details regarding specimen preparation are described in Section 8 of AASHTO T321. A general schematic of fixture used in the third-point fatigue test is shown in Figure 5.

The fatigue life and failure energy are used to estimate the resistance of hot mix asphalt mixtures to fatigue under repeated traffic loading. Although this is a simplified lab simulation test, the performance of hot mix asphalt can be more accurately predicted when the fatigue properties determined by this procedure are known.

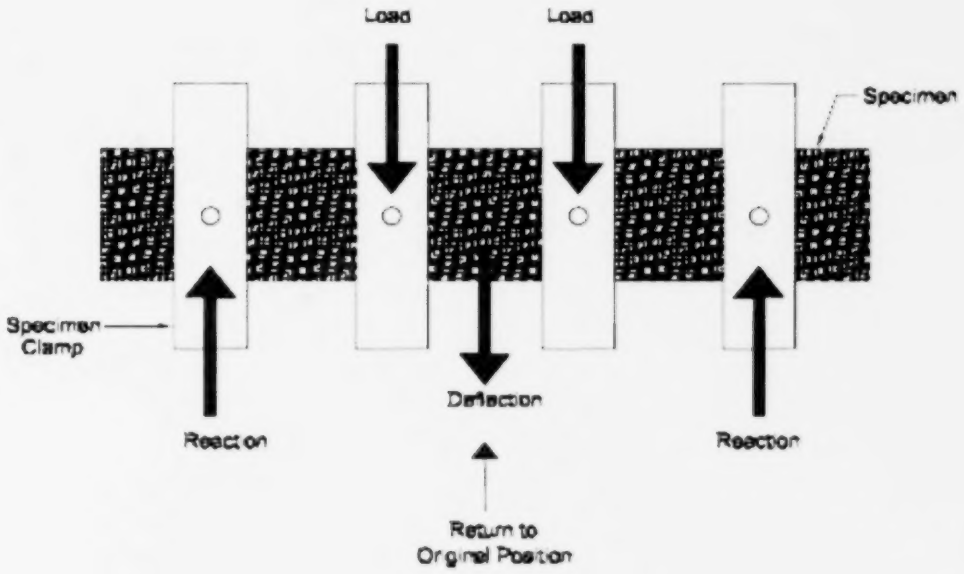

Figure 5. General Schematic of Beam Specimen Fixture Used in Flexural Fatigue Test

The test applies a cyclic load to the specimen mounted in a flexural bending device. This device transfers two symmetrical concentrated loads at the third-point of a simply supported beam specimen as shown in Figure 1 of AASHTO T321. The test can be conducted either under controlled stress (=constant load) or controlled strain (= constant deflection) mode.

The cyclic loading continues for a specified number of cycles or until the stiffness for the specimen drops to a specified percentage of the initial stiffness (e.g. 50%). The Operator can also terminate the test manually, if necessary.

Data collection during the test procedure includes the following signals:

- axial segment count (= count of load cycles),
- applied axial load, kN,
- deflection at the center of the beam for each of the installed LVDTs.

The load ramps to zero value and cycles between this end level and a second end level at a specified rate for a specified number of cycles or until the predetermined drop in the beam stiffness is reached.

The acquired data can also be plotted and updated on screen at selected intervals during the test. This update rate should be set at moderate level, e.g. every 3 to 5 seconds; otherwise the plotter may not be able to keep up due to the time needed for computer calculations taking place in real time.

For more details on Command Generation, Data Collection, Limit Detection, and Plotting, please refer to the MTS "TestStar IIs Asphalt Testing Manual", Chapter 3, or to the help files installed with the MTS software package.

7.2 SETUP FOR THE TEST

- Activate the computer and TestStar IIs controller, if this is not done yet.
- Open Station Manager application and – if it is the first test of the day - run a Warm-Up procedure (see Section 2.2).
- Ensure that the actuator and crosshead are properly positioned for the test.
- Mount the top connecting bar of the flexural fatigue test fixture securely in the upper grip.
- Raise the actuator so that the lower connecting bar of the fixture fits snugly in the lower grip. Close the lower grip securely.
- Prepare test specimen according to AASHTO T-321 (epoxy nuts on vertical sides at the neutral axis of the specimen).
- Select/open appropriate station configuration file (*.cfg), which contains a list of station resources / station parameter sets, applicable to your test procedure.
- Select the program source, MPT TestWare, on the main panel.

  If the AASHTO T321 test procedure has already been programmed and saved, select and Open your Procedure from the File menu. If the test procedure needs to designed or modified, select the MPT TestWare environment and (re)design the test sequence by (re)defining the entire sequence of events that are to take place within the test, using the tools available within the MPT programming environment. This requires some TestStar-specific programming experience.

Once the testing procedure is selected and opened, follow these steps:

1. Start the hydraulic pump (Low, then High) at the RSC, if not running at this point, and then enable the Manual control.
2. Open the clamps at the fixture and slide the specimen carefully into position.
3. Adjust the specimen position, if necessary, and close the clamps.

   Take care that the specimen is not subjected to any damaging bending force or displacement. Use a special jig, if available, to ensure proper horizontal spacing of the clamps. Close the outside clamps first; apply sufficient pressure to hold the specimen in place. Close the internal clamps and apply sufficient pressure to hold the specimen securely in place. Teflon paper can be used to reduce friction between the specimen surface and the clamps surface.
4. Switch to Force control and using the Manual control knob zero the load.
5. Attach the LVDT (**L**inear **V**ariable **D**ifferential **T**ransformer) block to the specimen so that the beam deflections at the neutral axis can be measured. Clamp the LVDTs into position.
6. Zero or rebalance the electronic measuring system; make sure that the LVDT readings are close to zero.

   The LVDTs should show stable readings, drifting no more than e.g. 10 to 50 μstrains over 100 seconds. This shows if the specimen is stabilized at a current test temperature.
7. After the measuring sensors stability is achieved, make sure that the system is in a desired mode of control and Disable the Manual control at the RSC.
8. On the MPT Control Panel, select an existing or create a new so-called "Specimen" before attempting to run the test procedure.

   This is a special folder (subdirectory) on your computer where all information about execution of a particular test will go. You must provide a name for this "Specimen"; otherwise MPT will display an error message. It should be a unique name, unless you want either to append new test information to the existing data files or to write over some existing information. Reset the station software interlocks (if vertical Red bars are present the hydraulic system will not start).
9. Reset any active interlocks (if vertical Red bars are present the procedure will not start).
10. Before starting the test, ensure again that the specimen is installed properly, sensors are attached and their outputs have been zeroed, and the actuator is properly positioned (the load is close to zero).
11. Switch to the **execute mode** by clicking the Padlock button on the MPT Control Panel.
12. Start the procedure by clicking the **Run** button on the MPT Control Panel.
13. When Pre-Test/Specimen information is required, fill in or change the information as necessary and click OK.

14. Click the **Start** button on the MPT Control Panel to continue the procedure.

15. Watch the procedure executing. You can click **Terminate** button any time during test execution to stop the procedure when necessary.

> If the system becomes unstable at any point, immediately press the **Emergency** STOP button at the RSC to remove hydraulic pressure. Identify the cause of the instability before attempting the test again.

16. When test is completed normally (successfully), enter the post-test information, if required, to finalize/exit the procedure.

    Note
    You can also stop the test (interrupt) *normally* at any time by clicking on **Stop** button on the main MPT panel. System will then return to Setpoint levels.

7.3 OUTPUT / RESULTS

Data collected during the test are automatically saved in a file called *specimen.dat*, in the folder created for the *specific specimen* tested.

To access the data, select ***Example Report Generator*** item under ***Programs> MTS Civil Engineering Materials Testing*** subdirectory. This selection will launch Excel version with an MTS menu. On the MTS menu, point to ***Data*** and click ***Open Raw Data***. From here locate and open the desired data file, i.e. ***specimen.dat*** in the subdirectory for your tested specimen.

At this point the Operator can select to use the MTS data analysis template (by pointing, on the MTS menu, to Test Definition -> Asphalt, and clicking the **Flexural Fatigue**) and proceed with data analysis, the MTS way.

Otherwise, the data file can be saved in Excel format (*.xls), with the Operator's choice of subdirectory and filename. The data can subsequently be analyzed using a customized spreadsheet template if such a template has been or will be developed in-house for this specific purpose.

Report on test results should include:

- hot mix asphalt description,
- specimen dimensions,
- average test temperature,
- table with columns showing: applied load, beam deflection, tensile stress and strain, flexural stiffness, phase angle, and dissipated energy, for each load cycle interval selected by the Operator,
- initial flexural stiffness,
- cycles to failure,
- plot of stiffness vs. load cycles, and
- plot of dissipated energy vs. load cycles.

8.0 Acknowledgements

This Operator's Guide is partially based on the training provided by Jim Pretty, former Lab Supervisor and long-term operator of the MTS system, to the bituminous lab staff as well as to students and other external lab staff. The author wishes to express gratitude for Jim's assistance and cooperation. His ingenuity and versatile skills were essential during every stage of the system operation, maintenance and troubleshooting.

Pamela Marks' editorial comments and suggestions regarding this Guide are also gratefully acknowledged.

9.0 References

1. *Reference Manual: 810 Materials Test System*, MTS Systems Corporation, Volumes 1 to 5, 1985/86.

2. *MTS Model 810 Materials Test System User's Manual*, MTS Systems Corporation, 1985.

3. *TestStar IIs Asphalt Testing Model 793.67. Software Installation, Reference, and User Information*, MTS Systems Corporation, 1999.

4. *Model 793.10 MultiPurpose TestWare®, User Information and Software Reference*, MTS Systems Corporation, 2003.

5. ASTM D3497-03, *Standard Test Method for Dynamic Modulus of Asphalt Mixtures.*

6. AASHTO TP62-03, *Standard Method of Test for Determining Dynamic Modulus of Hot-Mix Asphalt Concrete Mixtures.*

7. AASHTO T321, *Standard Method of Test for Determining the Fatigue Life of Compacted Hot-Mix Asphalt (HMA) Subjected to Repeated Flexural Bending.*

8. AASHTO T322, *Standard Method of Test for Determining the Creep Compliance and Strength of Hot-Mix Asphalt (HMA) Using the Indirect Tensile Test Device.*

9. *Bituminous Material Characterization Manual*, Bituminous Section, Engineering Materials Office, Ministry of Transportation, December 1987, ISBN 0-7729-3922-5.